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Model to a Base Year of 1980

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**REVISION OF THE INDUSTRIAL COMBUSTION EMISSIONS
MODEL TO A BASE YEAR OF 1980**

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ABSTRACT

The Industrial Combustion Emissions (ICE) Model is one of four stationary source emission and control cost forecasting models developed by the Air and Energy Engineering Research Laboratory for the National Acid Precipitation Assessment Program. The ICE Model projects air pollution emissions (sulfur dioxide, sulfates, nitrogen oxides, and particulate matter), costs and fuel mix for industrial fossil fuel-fired (natural gas, distillate and residual fuel oil and coal) boilers by State and year (1980 baseline, 1985, 1990, 1995, 2000, 2010, 2020, and 2030).

The ICE Model was originally developed from a data base of industrial boilers and fuel consumption in 1974. This report describes the development of an updated 1980 base year fuel consumption and air pollution emissions estimates data base by State. These 1980 base year data have been incorporated into ICE Model Versions 4.0, 5.0, and 6.0.

The ICE Model (Version 6.0) is available for remote terminal access and operation at the NCC. A transcription of the ICE Model is also available on magnetic tape. For information on operating the model at the NCC or obtaining a copy on magnetic tape, contact the National Technical Information Service (NTIS). Information can be obtained from Lois Grooms, NTIS, 5285 Port Royal Road, Springfield, VA 22161, 703/487-4808, or Larry Jones, USEPA, Air and Energy Engineering Research Laboratory, Mail Drop 62, Research Triangle Park, NC 27711, 919/541-7716.

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INTRODUCTION

The Industrial Combustion Emissions (ICE) Model is a highly disaggregated and detailed process engineering model covering the consumption of fossil fuels (coal, distillate fuel oil, residual fuel oil, and natural gas) in industrial boilers. It was developed by Energy and Environmental Analysis, Inc. (EEA) for EPA's Air and Energy Engineering Research Laboratory to help decision makers assess a wide range of energy, environmental, and cost impacts resulting from policy alternatives. The ICE Model is currently being used by the Interagency Task Force on Acid Precipitation to project the impacts of alternative acid deposition control strategies.

The ICE Model focuses on industrial boiler fuel choice decisions between alternative fossil fuels (i.e., coal, fuel oil, and natural gas). The model determines fuel choices for industrial boilers using projected industrial fuel prices and exogenous forecasts of industrial boiler total fossil fuel demand. The scope of the ICE Model does not include feedstock energy uses (e.g., metallurgical coal or raw materials derived from petroleum or natural gas in the chemical industry), energy consumption in process heat applications or non-fossil fuel combustion in industrial boilers (e.g., wood or bagasse). However, fossil fuels co-fired with non-fossil fuels are accounted for in emissions estimates.

The basic approach in this model is to project the characteristics of the industrial boiler population and to make a fuel choice decision for each group of boilers. Industrial boiler energy use is disaggregated by new (installed after the base year) and existing boilers of different sizes and annual capacity utilization rates. New and existing boilers are classified on the basis of the type of fuel they were designed to fire and whether they can be converted to fire alternative fuels.

The fuel choice decision criterion for new industrial boilers is based on an analysis of recent industrial boiler orders. It is a function of boiler size, location and previous coal experience as well as capital, O&M and fuel cost differences. Existing industrial boilers may switch fuels (i.e., change from residual fuel oil to natural gas combustion) and/or add pollution control

equipment in response to fuel price forecasts or changes in environmental regulations.

Major model outputs include:

- o Projected emissions of SO₂, sulfates, and NO_x
- o Projected industrial boiler fossil fuel demand by fuel type
- o Projected total capital and annual operating, maintenance, and fuel expenses.

Model outputs are available by State (excluding Alaska and Hawaii) and year (1985, 1990, 1995, 2000, 2010, 202, and 2030).

The base year in the Industrial Combustion Emissions (ICE) Model (Versions 1.0, 2.0 and 3.0) is 1974. This report describes the development of a 1980 data base of industrial fossil fuel-fired boiler characteristics which was incorporated in Version 4.0 of the ICE Model. This task was completed in September 1985.

DATA REQUIREMENTS

The following data elements are included in the ICE Model base year data file:

- o State (excluding Alaska and Hawaii)
- o Industry group (one of seven)
- o Fuel type (natural gas, distillate or residual fuel oil, or coal)
- o Boiler size class (MMBtu/hr, one of eight categories)
- o Annual capacity utilization rate (one of five categories)
- o Annual fossil fuel consumption
- o Pollution control equipment
- o Air Quality Control Region (AQCR)
- o State Implementation Plan (SIP) air emission limits by pollutant (SO₂, PM, and NO_x) and fuel type (residual fuel oil and coal)
- o Controlled emission rates for SO₂, sulfates, PM, and NO_x (which are a function of the fuel type, fuel firing method, pollution control equipment and air emission regulation).

A description of these data elements is available in another report.¹

APPROACH

The base year data in the ICE Model are an estimated distribution of existing industrial boiler characteristics (listed above), not a disclosure of proprietary data. Some of the data elements (i.e., specific boiler size and actual annual fuel consumption) are proprietary data elements on EPA's National Emissions Data System (NEDS), DOE/EIA's Large Combustor Survey (Form EIA-463) and DOE's Major Fuel Burning Installation (MFBI) Survey (Form C-602-S-0). Therefore, several ICE Model base year data elements (i.e., boiler size, annual capacity utilization rate and industry group) are represented as generic classes.

The 1974 base year data in Versions 1.0, 2.0 and 3.0 of the ICE Model are based on the MFBI Survey and NEDS data. The new 1980 base year data are based on estimates of new industrial watertube boiler sales between 1974 and 1980 and estimates of changes (between 1974 and 1980) in annual capacity utilization rates for industrial boiler capacity existing in 1974 and not retired by 1980.

Tables 1, 2 and 3 present American Boiler Manufacturers Association (ABMA) data on industrial watertube boiler sales. Industrial watertube boiler orders placed by domestic purchasers to domestic manufacturers declined substantially between the early 1970's and the 1980's.

EEA's Industrial Sector Technology Use Model (ISTUM-II) provides estimates of total industrial boiler consumption of natural gas, distillate and residual fuel oil and coal by industry group and Federal region in 1980. These estimates provide a benchmark for this analysis. A comparison of these aggregate, regional 1980 ISTUM-II estimates and the 1974 ICE Model estimates of industrial boiler total fossil fuel consumption indicates areas of growth (locations for new boilers) and decline (retirement or reductions in load factors between 1974 and 1980).

The U.S. Department of Commerce, Bureau of the Census 1980 Annual Survey of Manufactures (ASM) provides estimates of total (boilers and process heaters) purchased industrial fuel consumption by fuel type, industry group and State.² This data represents a second benchmark because the aggregate 1980 estimates in

TABLE 1. INDUSTRIAL WATERTUBE BOILER SALES DATA*

Year	Number of units	Total capacity (10 ⁶ PPH)**
1971	764	57.9
1972	769	57.3
1973	989	81.9
1974	785	78.6
1975	470	39.0
1976	384	31.0
1977	451	34.7
1978	299	30.6
1979	358	23.5
1980	317	30.8
1981	287	26.3
1982	204	16.6
1983+++	<200	<16.0
1984++++	<200	<20.0

*Industrial Boiler Sales. American Boiler Manufacturers Association. Prepared for the U.S. Environmental Protection Agency. March 18, 1983. Domestic steam and hot water units by year that the order was placed with the manufacturer. Excludes exports. Includes sales of "industrial-type" boilers to manufacturing plants, schools and hospitals and fuel types other than coal, oil and gas (i.e., wood, solid wastes, black liquor, combustible waste gas and waste heat).

**Million pounds of steam per hour.

+++Power. 128:179. November 1984.

++++Power. 129:179. November 1985.

TABLE 2. INDUSTRIAL WATERTUBE BOILER SALES DATA BY BOILER SIZE*
Number of units (total capacity, 10³ PPH)

Boiler capacity (10 ³ PPH)	1975	1976	1977	1978	1979	1980
10-16	37 (512)	23 (310)	34 (476)	10 (133)	23 (298)	15 (218)
16-100	308 (13,840)	250 (10,657)	269 (12,078)	246 (11,602)	288 (13,151)	233 (11,129)
100-250	88 (13,758)	91 (13,880)	76 (12,443)	62 (9,553)	25 (4,271)	36 (5,940)
250-500	14 (5,060)	8 (3,381)	7 (2,612)	8 (3,093)	15 (5,800)	16 (5,991)
Total	447 (33,170)	372 (28,228)	386 (27,609)	326 (24,381)	351 (23,520)	300 (23,278)

*Industrial Boiler Sales. American Boiler Manufacturers Association. Prepared for the U.S. Environmental Protection Agency. March 18, 1983. Domestic stationary units by year that the order was placed with the manufacturer. Excludes exports. Includes sales of "industrial-type" boilers to manufacturing plants, schools and hospitals and fuel types other than coal, oil and gas (i.e., wood, solid wastes, black liquor, combustible waste gas and waste heat).

TABLE 3. FUEL MIX OF TOTAL INDUSTRIAL
WATERTUBE BOILER SALES*
(Percentage, weighted by capacity)

Base fuel	1975	1976	1977	1978	1979	1980
Gas	38.0	27.5	23.4	18.0	19.5	15.2
Oil	30.3	38.1	30.5	39.9	32.7	23.8
Coal	7.7	7.2	21.2	9.3	13.5	23.1
Wood	5.1	6.6	6.8	17.7	18.0	12.3
Solid wastes	5.7	2.6	6.9	2.2	0.4	3.3
Other**	<u>13.2</u>	<u>18.0</u>	<u>11.2</u>	<u>12.9</u>	<u>15.9</u>	<u>22.3</u>
Total	100.0	100.0	100.0	100.0	100.0	100.0

*Industrial Boiler Sales. American Boiler Manufacturers Association.
Prepared for the U.S. Environmental Protection Agency. March 18, 1983.
Includes sales of "industrial-type" boilers to manufacturing plants, schools
and hospitals by year that the order was placed with the manufacturer. Not
directly comparable to Table 2 because Table 3 includes exports and Table 2
does not.

**Includes black liquor, combustible waste gas, and waste heat.

the ICE Model should be smaller than the 1980 ASM estimates for each State and industry group.

The basic approach, therefore, is to:

- 1) Estimate new industrial boiler data requirements not collected by ABMA (i.e., air emission rates, capacity utilization rate, pollution control equipment and SIPs).
- 2) Add estimates of new (installed between 1974 and 1980) industrial (excluding schools and hospitals) boiler annual fossil fuel (excluding wood, solid wastes, black liquor, combustible waste gas and waste heat) consumption to the ICE Model estimates for 1974.
- 3) Compare these preliminary ICE Model estimates for 1980 to the regional ISTUM-II industrial boiler total fossil fuel consumption estimates for 1980 and to State-level Commerce/ASM estimates of total (boiler and process heat) fossil fuel consumption estimates by industry group and State for 1980. Adjust the 1974 annual capacity utilization rate estimates (to reflect 1980 estimates) and retire boiler capacity for a small portion of the industrial boiler capacity existing in 1974 in the ICE Model (in order to normalize the aggregate estimates of industrial boiler total fossil fuel consumption in the ICE Model for 1980 to the regional ISTUM-II estimates for 1980).

RESULTS

Tables 4 and 5 present the 1980 ICE Model Version 4.0 base year data.

Table 4 summarizes EEA's estimates of total industrial fossil fuel-fired boiler SO₂ and NO_x emissions by State in 1980. These estimates are based on the assumption that all industrial fossil fuel-fired boilers were in compliance with applicable SO₂ and NO_x SIPs in 1980.

Table 5 summarizes EEA's estimates of industrial boiler fossil fuel consumption by fuel type and State in 1980. Natural gas is the primary industrial boiler fuel type in most of the Federal regions. Residual fuel oil is the primary fuel type in Federal regions 1 and 2. Coal is the primary industrial boiler fuel type in 1980 in Federal region 3.

TABLE 4. ESTIMATES OF AIR EMISSIONS FROM INDUSTRIAL
FOSSIL FUEL-FIRED BOILERS IN 1980*
(10³ short tons)

Federal region/state	SO ₂	NO _x
1. New England	52	17
Connecticut	9	4
Maine	22	5
Massachusetts	17	7
New Hampshire	2	0**
Rhode Island	1	1
Vermont	2	0**
2. New York/New Jersey	109	41
New Jersey	25	12
New York	84	29
3. Middle Atlantic	250	119
Delaware	10	4
Maryland/D.C.	22	13
Pennsylvania	109	55
Virginia	55	23
West Virginia	54	23
4. South Atlantic	368	139
Alabama	41	22
Florida	40	11
Georgia	76	21
Kentucky	16	9
Mississippi	1	2
North Carolina	73	28
South Carolina	64	19
Tennessee	57	27
5. Midwest	542	216
Illinois	96	44
Indiana	95	28
Michigan	71	48
Minnesota	14	10
Ohio	186	63
Wisconsin	79	23

(continued)

TABLE 4. (continued)

Federal region/state	SO ₂	NO _x
6. Southwest	147	129
Arkansas	17	8
Louisiana	88	25
New Mexico	2	4
Oklahoma	5	11
Texas	36	81
7. Central	47	27
Iowa	32	14
Kansas	5	5
Missouri	7	6
Nebraska	2	2
8. North Central	46	24
Colorado	7	7
Montana	3	1
North Dakota	3	1
South Dakota	1	0**
Utah	4	5
Wyoming	27	9
9. West	25	28
Arizona	2	3
California	22	24
Nevada	1	1
10. Northwest	17	23
Idaho	3	3
Oregon	7	9
Washington	7	10
U.S. Total (Lower-48)	1,603	762

*Emissions from industrial boilers burning natural gas, distillate fuel oil, residual fuel oil or coal.

**Less than 500 short tons.

TABLE 5. ESTIMATES OF INDUSTRIAL BOILER
FOSSIL FUEL CONSUMPTION IN 1980
(10¹² Btu)

Federal region/state	Natural gas	Distillate fuel oil	Residual fuel oil	Coal	Total
1. New England	23	10	104	0	137
Connecticut	4	3	23	0	30
Maine	0	1	38	0	39
Massachusetts	15	6	37	0	58
New Hampshire	0	0	2	0	2
Rhode Island	3	0	2	0	5
Vermont	1	0	2	0	3
2. New York/New Jersey	60	16	160	43	279
New Jersey	26	7	76	1	110
New York	34	9	85	42	169
3. Middle Atlantic	157	53	129	234	573
Delaware	5	4	11	4	23
Maryland/D.C.	37	16	24	12	89
Pennsylvania	87	15	57	109	268
Virginia	17	13	26	42	99
West Virginia	11	6	11	67	95
4. South Atlantic	327	68	277	190	862
Alabama	69	17	35	27	147
Florida	23	5	60	0	87
Georgia	52	11	68	13	144
Kentucky	26	6	5	22	59
Mississippi	12	0	1	0	13
North Carolina	38	14	59	44	156
South Carolina	36	6	36	31	110
Tennessee	71	10	13	53	146
5. Midwest	513	75	174	401	1,163
Illinois	173	27	84	39	323
Indiana	49	5	18	59	131
Michigan	97	22	15	100	234
Minnesota	42	2	7	12	64
Ohio	91	11	34	148	285
Wisconsin	60	8	15	43	127

(continued)

TABLE 5. (continued)

Federal region/state	Natural gas	Distillate fuel oil	Residual fuel oil	Coal	Total
6. Southwest	933	21	112	28	1,094
Arkansas	36	0	18	8	62
Louisiana	189	6	52	9	255
New Mexico	30	0	5	0	35
Oklahoma	68	6	1	9	83
Texas	611	10	35	2	658
7. Central	139	5	11	26	181
Iowa	53	4	5	21	83
Kansas	29	0	2	1	33
Missouri	38	0	3	2	43
Nebraska	19	0	1	1	22
8. North Central	92	3	45	20	160
Colorado	29	3	8	7	47
Montana	7	0	4	0	11
North Dakota	1	0	4	0	5
South Dakota	1	0	1	0	2
Utah	25	0	7	3	35
Wyoming	29	0	21	10	60
9. West	144	65	36	3	247
Arizona	15	5	3	1	23
California	127	60	33	0	220
Nevada	3	0	0	2	5
10. Northwest	146	1	24	8	179
Idaho	12	0	0	6	18
Oregon	65	0	9	2	77
Washington	68	1	15	0	85
U.S. Total (Lower-48)	2,534	317	1,071	954	4,876

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